JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 2000, **74,** 245–253 NUMBER 2 (SEPTEMBER)

DIFFERENTIAL OUTCOME EFFECT IN THE HORSE

YUKAKO MIYASHITA, SADAHIKO NAKAJIMA, AND HIROSHI IMADA

KWANSEI GAKUIN UNIVERSITY,
NISHINOMIYA, JAPAN

Three horses were trained with a discrimination task in which the color (blue or yellow) of a center panel signaled the correct (left or right) response (lever press). Reinforcing outcomes for the two correct color–position combinations (blue–left and yellow–right) were varied across phases. Discrimination performance was better when the combinations were differentially reinforced by two types of food (chopped carrot pieces and a solid food pellet) than when the combinations were randomly reinforced by these outcomes or when there was a common reinforcer for each of the correct combinations. However, the discrimination performance established by the differential outcome procedure was still 80% to 90% correct, and an analysis of two-trial sequences revealed that the stimulus color of the preceding trial interfered with discrimination performance on a given trial. Our demonstration of the differential outcome effect in the horse and its further analysis might contribute to more efficient control of equine behavior in the laboratory as well as in horse sports.

Key words: differential outcome effect, proactive interference, conditional discrimination, lever press, horses

The horse is one of the oldest of domestic animals, having lived with and been employed by humans for 6,000 years in such activities as agriculture, war, and sports (Budiansky, 1997). Both written and unwritten knowledge about equine behavior management has been accumulated, because the successful control of horse behavior depends on its training and management procedures. Scientific investigation of equine behavior, however, has a much shorter history (see McCall, 1990, for a review).

In the 1990s, behavioral studies of horses concentrated largely on stimulus discrimination learning, including tactile discrimination (Doughery & Lewis, 1993), peak shift in visual discrimination (Dougherty & Lewis, 1991), interocular transfer of visual discrimination (Hanggi, 1999b), learning set (Hanggi, 1997), categorization (Hanggi, 1999a), and psychophysical investigations of visual acuity, depth perception, and steropsis (Timney & Keil, 1992, 1996, 1999). Although these studies provided considerable information about the sensory systems and the discriminative behavior of this species, our knowledge is still limited and has not yet been widely used by equine trainers. In the present article, we explored a potentially more practical topic of discriminative behavior, which may contribute to a better behavioral technique for equine training.

A procedure for facilitating stimulus discrimination is to schedule a unique outcome for responding to each type of discriminative stimulus. This procedure results in good discrimination performance relative to ones with either a single outcome or randomly scheduled outcomes for correct responding (see Goeters, Blakely, & Poling, 1992, for a review). For example, Trapold (1970) trained rats to press one lever in the presence of a tone and to press a second lever in the presence of a click sound. Scheduling differential reinforcers (a food pellet and a small amount of sucrose solution) for correct responses under the individual auditory discriminative stimuli resulted in more accurate performance than delivery of a single common reinforcer (a pellet or a small amount of sucrose) for correct responses to both stimuli. Such a differential outcome effect has been

This article is based upon a thesis submitted in March 1998 by the first author in partial fulfillment of the Master of Psychology degree from Kwansei Gakuin University. The experiment and analysis were conducted by her under the supervision of the second author, who prepared this article. The entire horse project began with Nobuyuki Kawai, and without his effort this project would not have been launched. We are grateful to members of the Kwansei Gakuin University Riding Club for their support. The first author thanks Michiko Nakajima, Kota Kaneshige, Nobutaka Doe, Kosuke Sawa, and Kouji Urushihara for encouragement of the study. She also thanks a superb equestrian, Eiichi Fukunaga, for his encouragement and assistance.

Correspondence regarding this article should be sent to Sadahiko Nakajima, Department of Psychology, Kwansei Gakuin University, Nishinomiya, Hyogo 662-8501, Japan (E-mail: nakajima@kwansei.ac.jp).

demonstrated with pigeons (e.g., Peterson, Wheeler, & Trapold, 1980; Urcuioli, 1990), chickens (Poling, Temple, & Foster, 1996), rats (e.g., Fedorchak & Bolles, 1986; Trapold, 1970), dogs (Overmier, Bull, & Trapold, 1971), and normal (P. Maki, Overmier, Delos, & Gutmann, 1995) and developmentally disabled children (e.g., Saunders & Sailor, 1979). To our knowledge, however, there is no demonstration of the differential outcome effect in horses or any other ungulates. The possibility of better discriminative performance with a differential outcome procedure, therefore, seemed to be worth investigating for its potential practical value in equine training.

Three horses were trained to respond to one of two simultaneously presented levers as a function of the visual stimulus correlated with each lever. When the stimulus was blue, a press on one lever was rewarded, and the yellow stimulus was discriminative for reinforcement of a response on the other lever. Such a task has been labeled a two-choice successive discrimination of two visual stimuli (Goeters et al., 1992), or the discrimination of positions conditional upon the stimuli presented (Fedorchak & Bolles, 1986). However it is labeled, this type of procedure has been widely employed to demonstrate the differential outcome effect in rats with auditory stimuli (e.g., Fedorchak & Bolles, 1986; Trapold, 1970) and in pigeons with visual stimuli (Williams, Butler, & Overmier, 1990). This task, therefore, seemed to be a good choice for demonstrating the differential outcome effect in the horse.

Although between-groups comparisons have been conventionally used to study the differential outcome effect, the effect has also been reported using a within-subject repeated reversal design (e.g., Alling, Nickel, & Poling, 1991; Peterson, Wheeler, & Armstrong, 1978; Saunders & Sailor, 1979). Because of the small number of subjects in the present study, we employed a within-subject design to examine the efficacy of the differential outcome procedure in equine discriminative performance.

METHOD

Subjects

Three thoroughbred horses were chosen as subjects from a pool of 20 retired racing horses owned by the Kwansei Gakuin University Riding Club. The 3 were chosen because they neither bit often nor broke the apparatus when being adapted to it. Summer Snow was a 15-year-old gelding that had a history of lever pressing with its lips. Tsuki-haya was a 16-year-old gelding that had participated in an autoshaping study (Miyashita, Nakajima, & Imada, 1999). Tsuki-kiri was an experimentally naive 18-year-old mare. They were fed three times a day (morning, noon, and evening), and each daily experimental session took place immediately prior to the evening feeding with hay.

Apparatus

Individual horses were guided into an experimental stall 270 cm wide, 305 cm long, and 263 cm high. The stall consisted of cement-block walls, a wooden ceiling, and an earth floor covered with straw. The wall opposite to the entry door had a vertical plywood unit 90 cm wide and 190 cm high. This unit contained a clear acrylic center panel, a metal food tray, and two retractable metal levers. The center work panel (18 cm by 18 cm) was located 112 cm above the floor. Two 100-W bulbs with colored plastic plates projected blue (250 cd/m^2) or yellow (500 cd/m^2) light onto the panel from the back. A recent study by Macuda and Timney (1999) showed that horses have color vision for blue but not yellow. Our description of colors is nominal, and whether the horses saw these colors as we do is not crucial for the purpose of our study. The panel could also be illuminated white by removing the colored plates. The food tray was 19.5 cm in diameter and 8 cm in depth and was centered 40 cm below the panel. Each of the levers was 4.6 cm wide and 0.2 cm thick, and each could be protruded 2.2 cm from the unit board. Presses on these levers (0.2 N) were detected by a microswitch. The center of each lever was 31.5 cm from the midline of the work panel and 96 cm above the floor. A semiautomatic feeder behind the unit delivered either a balanced food pellet (Ace Ration, Nihon Nosan Kogyo Co.) or three pieces of fresh carrot from individual dispensers into the tray. The pellet and the carrot piece were of equal size (1 cm by 1 cm by 1 cm). A 3-s sound of an electric chime (2300 Hz, EB2134, Matsushita Electric Works, Ltd.) accompanied the reinforcer delivery. An experimenter sat quietly behind the work panel and delivered the reinforcers to the dispensers several times a session. She was not visible to the subjects. A microcomputer and a programmable circuit controlled the stimuli and recorded panel-touch responses. A videocamera fixed on the wall recorded the horses' behavior from the right side.

Procedure

Adaptation and magazine training. Although Summer Snow and Tsuki-haya previously had participated in learning experiments with the same apparatus, they, as well as Tsuki-kiri, were given pretraining. After reactions to the chime and the retractions of the levers were habituated, each subject was trained to approach to the food tray and eat pellets and carrot pieces from the tray. Thirty reinforcers each of the pellet and the carrot were given in one session.

Shaping lever pressing. Shaping of the lever press was instituted by differential reinforcement of successive approximations. With one of the levers protruded, pressing it with lips was manually shaped and maintained with one of the reinforcers (randomly determined each time). The panel was always lit white. Then each horse was trained with 80 reinforcers to respond equally to two protruded levers in the following way. Each block of eight reinforcement opportunities consisted of four reinforcers each for responses to the left and right levers, and pressing more than four times on the same lever did not deliver further reinforcers in a given block. The two types of reinforcers were delivered equally often. The panel was permanently lit white, and the levers protruded into the stall throughout the session. This training continued for two sessions.

Multiple-schedule preliminary training. To establish stimulus control of a panel light over lever pressing, each subject was trained to respond in the presence of a white light on the panel for 31 sessions. The two types of reinforcers were arranged in a random order with the limitation that 30 of each type of reinforcer occurred in a given session. During each of the initial 12 sessions, a component began with the onset of the white panel light and the simultaneous insertion of both levers: A response to either lever delivered a reinforcer during this component. When the panel light was turned off, the levers were retracted to preclude further responses and no food was presented. Initially, the light-on and light-off components were 30 s and 5 s long, respectively. The duration of the light-off component was increased by 5 s every two sessions until it was 30 s in duration. At this point, a multiple continuous-reinforcement extinction schedule was introduced and remained for the following 19 sessions. During this multiple schedule both levers were always available, and the discriminative stimuli alternated. Durations of the light-on and light-off components, respectively, were 30 s and 30 s for nine sessions and then 30 s and 60 s for one session. The component durations were shortened during the last nine sessions. Here, the light-on components were 5 s long on average and the light-off components were 12.5 s long on average.

Discriminative choice training. Following preliminary training, the subjects received discrimination training with two colors. A trial began with the onset of the light, colored blue or yellow, on the center panel, followed 3 s later by the simultaneous insertion of both levers. A single press on the correct lever (the left lever when the panel was blue; the right lever when it was yellow) turned off the panel light, retracted the levers, and delivered a reinforcer. An intertrial interval (ITI) then preceded the next trial in the sequence. An incorrect choice (i.e., a single press on the other lever) turned off the panel light and retracted the levers, but no reinforcer was delivered. Each session consisted of 60 trials, and there were no correction trials. The value of the ITI preceding a given trial was chosen equally often, in a random order, from the set of 5, 10, 15, and 20 s, resulting in an average ITI value of 12.5 s. A Gellermann (1933) series was employed to create quasi-random trial orders for individual sessions.

In the differential outcome phase, the reinforcer for the correct blue–left pairs was carrot pieces and that for the correct yellow–right pairs was a pellet for each subject. These two kinds of reinforcers were presented randomly for correct responses during the mixed outcome phase. The reinforcer was always the carrot pieces in the first common outcome phase and the pellet in the second common outcome phase. A phase was changed to the next when a given horse's performance seemed stable by visual inspection of the graphed data.

Summer Snow initially was trained with the differential outcome procedure for 18 sessions, which was followed by the mixed outcome phase for 12 sessions. This was followed by a second differential outcome phase for nine sessions. Tsuki-kiri began with the mixed outcome procedure (18 sessions), followed by a differential outcome phase (21 sessions), then a second mixed outcome phase (12 sessions), and finally a second differential outcome phase (12 sessions). Tsuki-haya was the only animal that was studied using the common outcome procedure, and the order of the conditions and the number of sessions at each were as follows: the differential outcome phase (24 sessions), then the carrot common outcome phase (15 sessions), then the second differential outcome phase (15 sessions), and finally the pellet common outcome phase (nine sessions).

RESULTS

Differential Outcome Effect

Figure 1 shows the percentage of correct responses during the discriminative choice training with two colors. The top graph shows that Summer Snow gradually learned the problem in the first differential outcome phase. The discrimination performance deteriorated abruptly to 73% correct when the mixed outcome procedure was introduced, and there was no improvement during the next 11 sessions. Reinstatement of the differential outcome procedure immediately increased percentage of correct responses followed by a continued steady increase up to 90% correct.

As shown in the middle graph of Figure 1, Tsuki-kiri started with the mixed outcome phase, and its performance did not improve over 18 sessions. This poor performance was due primarily to a position preference for the left lever (not shown in Figure 1). Across the 18 sessions, 71% of the responses were on this lever (recall that we did not employ a correction procedure). When switched to the differential outcome procedure, the horse began to learn the task and the position preference gradually decreased. Discrimination accuracy dropped about 10 points when the mixed outcome procedure was reinstated, and it remained around 75% correct for 12 sessions. Recovery of performance occurred when the differential outcome procedure was reinstated, and the horse made about 90% correct responses.

These results indicate that the differential outcome procedure is more effective than the mixed outcome procedure in training the present discriminative task and maintaining good discriminative performance. The data for Tsuki-haya, shown in the bottom graph of Figure 1, on the other hand, demonstrate the effectiveness of the differential outcome procedure by comparing it with the two common outcome procedures. Approximately 80% correct responses occurred during the differential outcome procedure, but the performance deteriorated when all reinforcers were changed to carrot pieces in the first common outcome phase. Although there was some recovery of discrimination performance in the later sessions of this phase, the percentage correct dropped to 60% during the last session. Reinstating the differential outcome procedure resulted in gradual increases in discrimination performance, ultimately exceeding the final level of the first differential outcome phase. Changing to the condition in which all reinforcers were food pellets resulted in gradual decreases in accuracy to around 70% correct.

Effect of the Preceding Trial

Although arranging differential outcomes resulted in good discrimination performance in each animal, accuracy was not perfect, hovering instead around a level of 80% to 90% correct. Because the panel was still lit when the horse chose the levers, we expected even better performance. Therefore, we conducted post hoc analyses of the differential outcome data.

Figure 2 shows the percentage of correct responses during the differential outcome phase as a function of the preceding trial type. This analysis was based on the last five sessions of each differential outcome phase, with the data of the first trial of each session excluded because there was no preceding trial for that trial. The left graphs of Figure 2 show each animal's performance when the color of the stimulus panel on a given trial

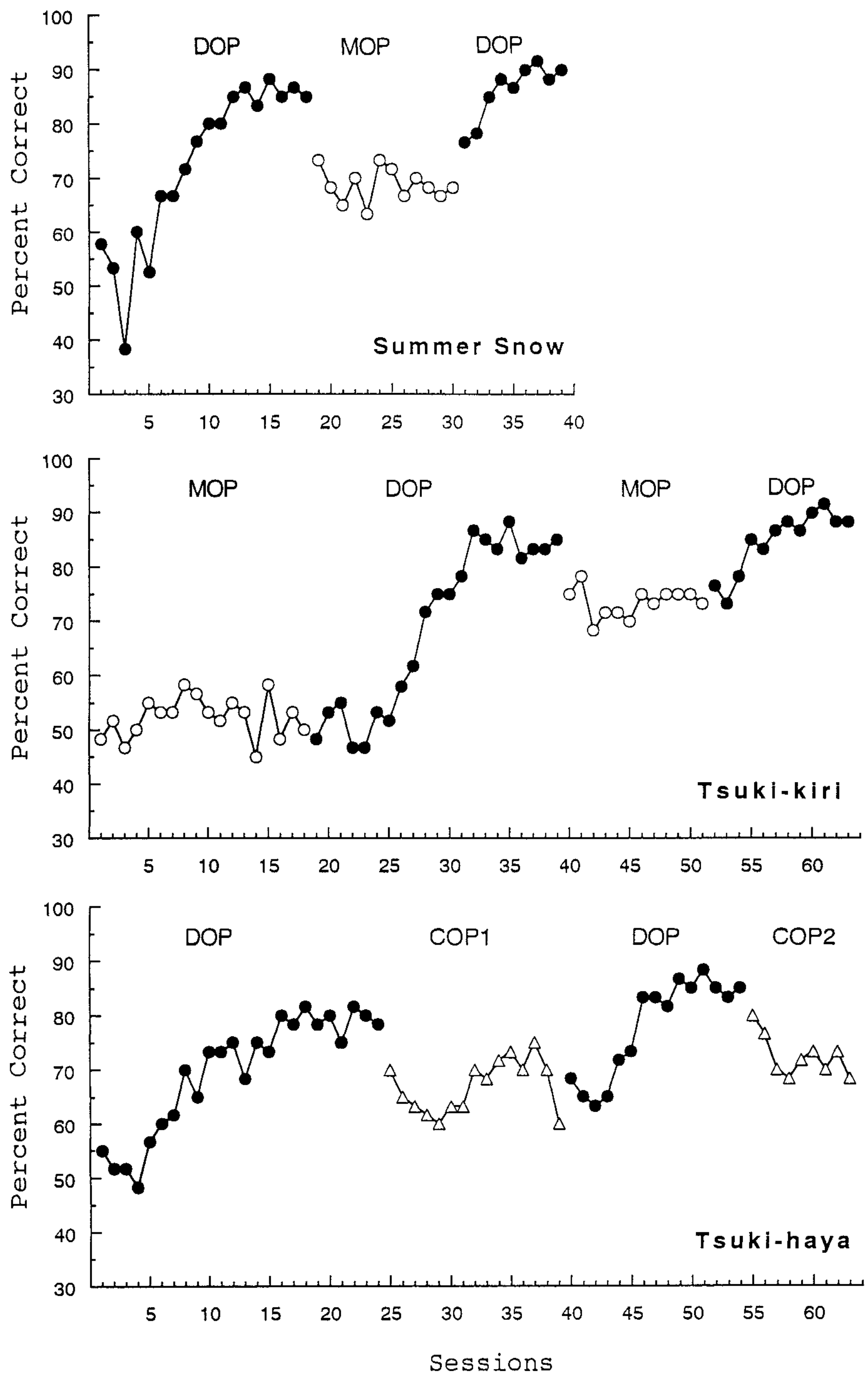

Fig. 1. Percentage of correct responses of each horse during the discriminative choice training with two colors. DOP = differential outcome procedure; MOP = mixed outcome procedure; COP1 = common outcome procedure with carrot pieces; COP2 = common outcome procedure with a food pellet.

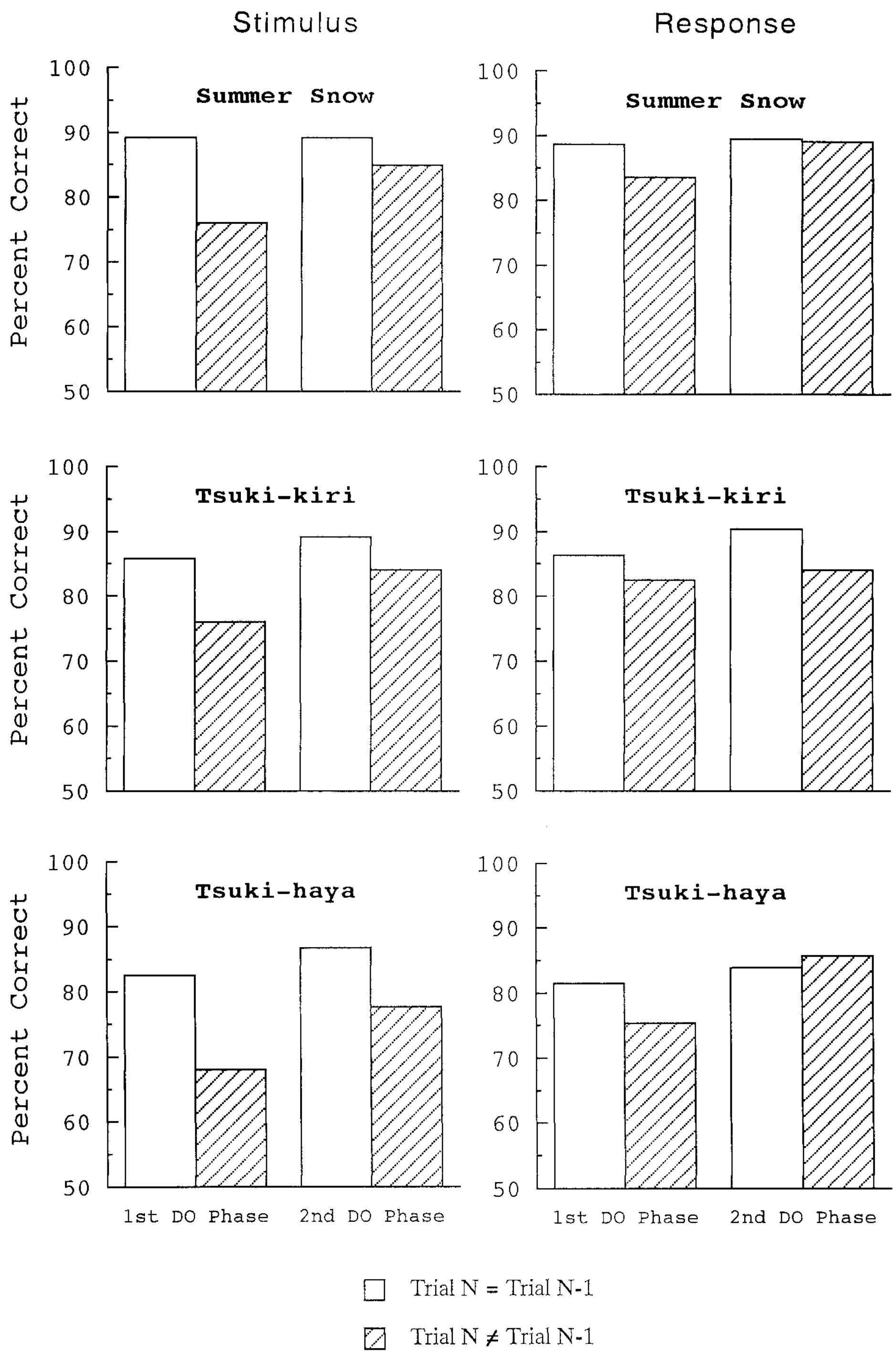

Fig. 2. Percentage of correct responses of each horse in the first and second differential outcome (DO) phases as a function of two-trial sequence agreement. Left graphs separately show the performance when the color of the stimulus panel on a given trial (trial n) was the same as or different from that of the preceding trial (trial $n - 1$). Right graphs show the performance when the correct lever on trial n was the lever selected on trial $n - 1$ and that when the correct choice on trial n was the lever not selected on trial $n - 1$.

Table 1

Percentage correct responses on trial n as a function of types of the reinforcer delivered on trial $n - 1$. The percentages are shown separately for colors of the center panel on trial n. Each value is based upon the total observations in 10 sessions of differential outcomes (the last five sessions each of two differential outcome phases), in which blue-left-carrot and yellow-right-pellet combinations were arranged.

	Carrot		Pellet		No delivery	
Subject	Blue	Yellow	Blue	Yellow	Blue	Yellow
Summer Snow	91.38	86.58	88.06	88.14	86.05	67.86
Tsuki-kiri	92.38	91.45	90.60	89.52	65.85	58.54
Tsuki-haya	89.80	92.78	83.65	85.61	57.14	56.36

(trial n) was the same as or different from that of the preceding trial (trial $n - 1$). Percentage of correct responses was consistently lower for each horse when the preceding trial was different from the present trial, suggesting proactive interference from the preceding trial stimulus.

The same data may be reexamined in terms of response, rather than stimulus, transitions, to determine whether a choice response on trial $n - 1$ affected performance on trial n (the right graphs of Figure 2). A positive transition means that the correct lever on trial n was the lever selected on trial $n - 1$, whereas a negative transition signifies that the correct choice on trial n was the lever not selected on trial $n - 1$. Although accuracy was higher on positive transition trials than on negative transition trials in the first differential outcome phase for each subject, the effect was smaller than that found in the stimulus transition analysis. Futhermore, the effect disappeared in the second differential outcome phase for Summer Snow and Tsuki-haya. Hence, interference from the choice response in the preceding trial was small relative to that from the signal stimulus of the preceding trial.

Another way of analyzing trial transitions is to determine whether a trial outcome in trial $n - 1$ affected performance on trial n. Table 1 summarizes the results of this analysis, and the data in it show little evidence of control by reinforcer type of performance on the next trial. The poor performance after the nondelivery of any reinforcers suggests that the horses tended to make successive errors. Emotional behavior induced by nonreinforcement may have precluded accurate performance on the next trial. Also, distracting stimuli (e.g., outside noise) may have affected performance, resulting in incorrect choices during that period. We have no basis for choosing between these accounts.

Effect of the Preceding ITI

Because we employed a variable ITI schedule consisting of four lengths, discrimination performance can also be analyzed as a function of the lengths of the preceding ITI (Figure 3). The data were taken from the last five sessions of each differential outcome phase, with the data of the first trial excluded because there was no preceding trial for this trial. The ITI length had no systematic effect with Summer Snow. For Tsuki-kiri, the shortest ITI prior to a given trial caused poor performance in the first differential outcome phase, although this effect disappeared in the second differential outcome phase. The ITI length clearly affected accuracy in Tsuki-haya; up to a 15-s ITI, the longer the ITI, the better the performance. This pattern was found in both differential outcomes phases, although the ITI effect was less in the second phase due to increased accuracy following shorter ITI values.

DISCUSSION

The results with 3 horses demonstrated a differential outcome effect by comparing the differential procedure with two conventional control procedures (i.e., mixed and common procedures; cf. Peterson, 1984). Scheduling differential reinforcers (carrot pieces and a food pellet) for correct pairs of blue–left and yellow–right facilitated the discriminative performance of Summer Snow and Tsuki-kiri relative to a condition with nondifferential or mixed arrangements of these reinforcers. Because the differential and mixed procedures

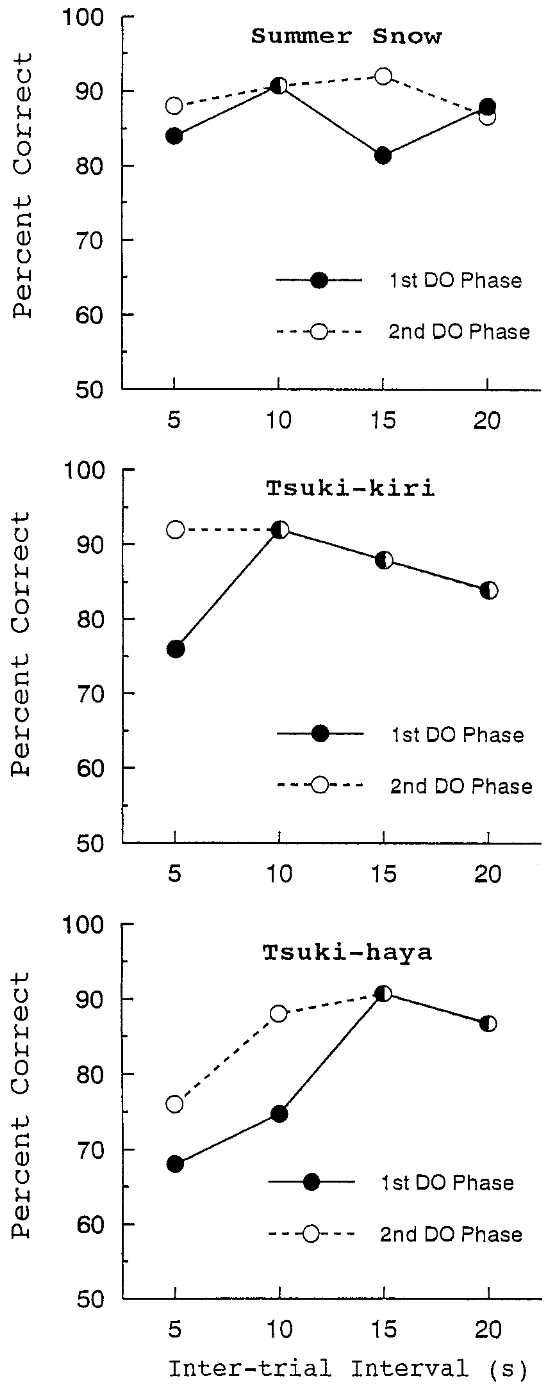

Fig. 3. Percentage of correct responses of each horse in the first and second differential outcome (DO) phases as a function of the ITI length preceding trials.

employed the two reinforcers equally, better performance in the former procedure cannot be attributed to differences in reinforcer satiation between these two procedures.

Although there were two positive stimulus–response–reinforcer links in the differential procedure (i.e., blue–left–carrot and yellow–right–pellet), there were four in the mixed procedure (i.e., blue–left–carrot, blue–left–pellet, yellow–right–carrot, and yellow–right–pellet). This factor potentially could contribute to the differences in discrimination performance between these procedures. The results for Tsuki-haya, however, argue against such an interpretation. A single, or common, reinforcer procedure was compared with the differential procedure in this animal. The reinforcer was always a carrot in the first common phase and a food pellet in the second common phase. This common procedure yielded poorer accuracy than did the differential procedure, even though the animal's responses were reinforced in a consistent way in both procedures and the number of positive three-term links was equivalent (i.e., two) for these procedures. One may argue that the common procedure caused more within-session reduction in reinforcing value than the differential procedure because the former employed a single reinforcer over the session and that a difference in reinforcer satiation resulted in the poorer performance. As noted above, this account does not explain the results of Summer Snow and Tsuki-kiri, for which the differential procedure was pitted against the mixed, rather than the common, procedure.

Traditionally, the differential outcome effect has been accounted for by expectancy theory. Individual stimulus–reinforcer combinations among the stimulus–response–reinforcer contingencies in a differential outcome procedure make the stimuli evoke specific outcome expectancies, which in turn provides animals with additional discriminative cues for responding (Peterson, 1984; Trapold & Overmier, 1972). In some studies (e.g., Alling et al., 1991; Brodigan & Peterson, 1976; Urcuioli, 1990), unique overt responses reflecting such "specific outcome expectancies" were reported. Unfortunately, we could not find from the recorded video images of our horses any reliable differential overt responses corresponding to individual stimuli. It is possible that specific outcome expectancies were private events such as differential secretion of salivation (Goeters et al., 1992) or central neuron activities (cf. Watanabe, 1996). Unless the nature of this process is better explored, we cannot evaluate the validity of expectancy theory behaviorally.

The discrimination performance of the horses tested here was less than perfect even with differential outcomes, in part because accuracy was at least partially controlled by the type of preceding trial. As shown in the analysis of two-trial sequences, the stimulus color of the preceding trial affected discrimination performance on a given trial. Performance was better when the colors of the successive trials were identical than when they were different. Such an effect has been reported with pigeons (e.g., Edhouse & White, 1988; Roberts, 1980; Roitblat & Scopatz, 1983), rats (e.g., Roitblat & Harley, 1988), monkeys (e.g., Moise, 1976), and a dolphin (Herman, 1975) in delayed matching-to-sample tasks in which a sample stimulus on the preceding trial affected the performance of a given trial.

Some researchers (e.g., Edhouse & White, 1988; Roberts, 1980; Roitblat & Scopatz, 1983), however, have argued that such results relate to the previously chosen comparison stimulus rather than the previous sample stimulus. The data of these researchers, along with the reanalysis of Moise's (1976) results conducted by Wright, Urcuioli, and Sands (1986) support this argument. However, this suggestion does not apply to the discriminative choice task studied here because the effect of the choice response of the preceding trial was small relative to that from the discriminative stimulus of the preceding trial.

The ITI also has been described as a critical factor in conditional discrimination tasks such as delayed matching to sample with pigeons (e.g. Edhouse & White, 1988; Kraemer & Roberts, 1984; W. S. Maki, Moe, & Bierley, 1977; Roberts, 1980; Roitblat & Scopatz, 1983), rats (e.g., Roitblat & Harley, 1988), monkeys (e.g., Jarrard & Moise, 1971; Mason & Wilson, 1974), and a dolphin (Herman, 1975): The longer the ITI, the better the performance. In the present study, only 1 of the 3 horses showed such an effect. This is probably because the ITI varied in length from trial to trial within a session in our study. The studies noted above explored the effect by manipulating ITI lengths across sessions or phases. As a result, the within-session accumulation of proactive interference or fatigue by massed trials affected performance.

Our demonstration of the differential outcome effect in horses is a systematic replication (Sidman, 1960) of an important behavioral phenomenon, and it provides interspecies generality of the differential outcome effect. The demonstration also has practical implications. Efficient control of equine behavior is required on the fields of horse sports such as racing, riding, and polo, where vocal and tactile commands work as discriminative cues. Differential outcomes for the individual cues could enhance command control over behavior of the horse. Hence, we believe our research can contribute more scientific and efficient techniques for future equine training and management. The differential outcome procedure would also be helpful in behavioral studies of the sensory systems of individual animals and of the species under investigation. For instance, one may have concluded incorrectly from the nondiscriminative performance in the initial phase (see the middle graph of Figure 1) that Tsuki-kiri lacked the visual physiology necessary for discrimination of the stimuli employed here. The differential outcome procedure could prevent such a premature conclusion and provide a more accurate picture of the sensory capabilities of animals.

REFERENCES

Alling, K., Nickel, M., & Poling, A. (1991). The effects of differential and nondifferential outcomes on response rates and accuracy under a delayed-matching-to-sample procedure. *The Psychological Record, 41,* 537–549.

Brodigan, D. L., & Peterson, G. B. (1976). Two-choice conditional discrimination performance of pigeons as a function of reward expectancy, prechoice delay, and domesticity. *Animal Learning & Behavior, 4,* 121–124.

Budiansky, S. (1997). *The nature of horses: Exploring equine evolution, intelligence and behavior.* New York: Free Press.

Dougherty, D. M., & Lewis, P. (1991). Stimulus generalization, discrimination learning, and peak shift in horses. *Journal of the Experimental Analysis of Behavior, 56,* 97–104.

Dougherty, D. M., & Lewis, P. (1993). Generalization of a tactile stimulus in horses. *Journal of the Experimental Analysis of Behavior, 59,* 521–528.

Edhouse, W. V., & White, K. G. (1988). Sources of proactive interference in animal memory. *Journal of Ex-*

perimental Psychology: Animal Behavior Processes, 14, 56–70.

Fedorchak, P. M., & Bolles, R. C. (1986). Differential outcome effect using a biologically neutral outcome difference. *Journal of Experimental Psychology: Animal Behavior Processes, 12,* 125–130.

Gellermann, L. W. (1933). Chance orders of alternating stimuli in visual discrimination experiments. *Journal of Genetic Psychology, 42,* 206–208.

Goeters, S., Blakely, E., & Poling, A. (1992). The differential outcomes effect. *The Psychological Record, 42,* 389–411.

Hanggi, E. B. (1997). The learning to learn phenomenon. *Savvy: The International Journal of Parelli Natural Horsemanship, 2,* 38–41.

Hanggi, E. B. (1999a). Categorization learning in horses (*Equus caballus*). *Journal of Comparative Psychology, 113,* 243–252.

Hanggi, E. B. (1999b). Interocular transfer of learning in horses (*Equus caballus*). *Journal of Equine Veterinary Science, 19,* 518–524.

Herman, L. M. (1975). Interference and auditory short-term memory in the bottlenosed dolphin. *Animal Learning & Behavior, 3,* 43–48.

Jarrard, L. E., & Moise, S. L. (1971). Short-term memory in the monkey. In L. E. Jarrard (Ed.), *Cognitive processes of nonhuman primates* (pp. 1–24). New York: Academic Press.

Kraemer, P. J., & Roberts, W. A. (1984). Short-term memory for visual and auditory stimuli in pigeons. *Animal Learning & Behavior, 12,* 275–284.

Macuda, T., & Timney, B. (1999). Luminance and chromatic discrimination in the horse (*Equus caballus*). *Behavioural Processes, 44,* 301–307.

Maki, P., Overmier, B. J., Delos, S., & Gutmann, A. J. (1995). Expectancies as factors influencing conditional discrimination performance of children. *The Psychological Record, 45,* 45–71.

Maki, W. S., Jr., Moe, J. C., & Bierley, C. M. (1977). Short-term memory for stimuli, responses, and reinforcers. *Journal of Experimental Psychology: Animal Behavior Processes, 3,* 156–177.

Mason, M., & Wilson, M. (1974). Temporal differentiation and recognition memory for visual stimuli in rhesus monkeys. *Journal of Experimental Psychology, 103,* 383–390.

McCall, C. A. (1990). A review of leaning behavior in horses and its application in horse training. *Journal of Animal Science, 68,* 75–81.

Miyashita, Y., Nakajima, S., & Imada, H. (1999). Panel-touch behavior of horses established by an autoshaping procedure. *Psychological Reports, 85,* 867–868.

Moise, S. L., Jr. (1976). Proactive effects of stimuli, delays, and response position during delayed matching from sample. *Animal Learning & Behavior, 4,* 37–40.

Overmier, J. B., Bull, J. A., & Trapold, M. A. (1971). Discriminative cue properties of different fears and their role in response selection in dogs. *Journal of Comparative and Physiological Psychology, 76,* 478–482.

Peterson, G. B. (1984). How expectancies guide behavior. In H. L. Roitblat, T. G. Bever, & H. S. Terrace (Eds.), *Animal cognition* (pp. 135–148). Hillsdale, NJ: Erlbaum.

Peterson, G. B., Wheeler, R. L., & Armstrong, G. D. (1978). Expectancies as mediators in the differential-reward conditional discrimination performance of pigeons. *Animal Learning & Behavior, 6,* 279–285.

Peterson, G. B., Wheeler, R. L., & Trapold, M. A. (1980). Enhancement of pigeons' conditional discrimination performance by expectancies of reinforcement and nonreinforcement. *Animal Learning & Behavior, 8,* 22–30.

Poling, A., Temple, W., & Foster, T. M. (1996). The differential outcomes effect: A demonstration in domestic chickens responding under a titrating-delayed-matching-to-sample procedure. *Behavioural Processes, 36,* 109–115.

Roberts, W. A. (1980). Distribution of trials and intertrial retention in delayed matching to sample with pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 6,* 217–237.

Roitblat, H. L., & Harley, H. E. (1988). Spatial delayed matching-to-sample performance by rats: Learning, memory, and proactive interference. *Journal of Experimental Psychology: Animal Behavior Processes, 14,* 71–82.

Roitblat, H. L., & Scopatz, R. A. (1983). Sequential effects in pigeon delayed matching-to-sample performance. *Journal of Experimental Psychology: Animal Behavior Processes, 9,* 202–221.

Saunders, R. R., & Sailor, W. (1979). A comparison of three strategies of reinforcement on two-choice learning problems with severely retarded children. *AAESPH Review, 4,* 323–333.

Sidman, M. (1960). *Tactics of scientific research: Evaluating experimental data in psychology.* New York: Basic Books.

Timney, B., & Keil, K. (1992). Visual acuity in the horse. *Vision Research, 32,* 2289–2293.

Timney, B., & Keil, K. (1996). Horses are sensitive to pictorial depth cues. *Perception, 25,* 1121–1128.

Timney, B., & Keil, K. (1999). Local and global steropsis in the horse. *Vision Research, 39,* 1861–1867.

Trapold, M. A. (1970). Are expectancies based upon different positive reinforcing events discriminably different? *Learning and Motivation, 1,* 129–140.

Trapold, M. A., & Overmier, J. B. (1972). The secondary learning process in instrumental learning. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning: Vol 2. Current research and theory* (pp. 427–452). New York: Appleton.

Urcuioli, P. J. (1990). Some relationships between outcome expectancies and sample stimuli in pigeons' delayed matching. *Animal Learning & Behavior, 18,* 302–314.

Watanabe, M. (1996). Reward expectancy in primate prefrontal neurons. *Nature, 382,* 629–632.

Williams, D. A., Butler, M. M., & Overmier, J. B. (1990). Expectancies of reinforcer location and quality as cues for a conditional discrimination in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 16,* 3–13.

Wright, A. A., Urcuioli, P. J., & Sands, S. F. (1986). Proactive interference in animal memory. In D. F. Kendrick, M. E. Rilling, & M. R. Denny (Eds.), *Theories of animal memory* (pp. 101–125). Hillsdale, NJ: Erlbaum.

Received January 5, 2000
Final acceptance May 22, 2000